

Selected Abstracts from Other Physical Review Journals

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Sign of the day-night asymmetry for solar neutrinos. Cheng-Wei Chiang and Lincoln Wolfenstein, *Department of Physics, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213*. (Received 7 November 2000; published 8 February 2001)

A qualitative understanding of the day-night asymmetry for solar neutrinos is provided. The greater night flux in ν_e is seen to be a consequence of the fact that the matter effect in the Sun and that in the Earth have the same sign. It is shown in the adiabatic approximation for the Sun and constant density for the Earth that, for all values of the mixing angle θ_V between 0 and $\pi/2$, the night flux of neutrinos is greater than the day flux. Only for small values of θ_V where the adiabatic approximation badly fails does the sign of the day-night asymmetry reverse. [Phys. Rev. D **63**, 057303 (2001)]

What is the big-bang-nucleosynthesis prediction for the baryon density and how reliable is it? Scott Burles, *Experimental Astrophysics Group, Fermi National Accelerator Laboratory, Box 500, Batavia, Illinois 60510-0500 and Department of Astronomy and Astrophysics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433*; Kenneth M. Nollett, *Department of Physics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433 and Physics Division, Argonne National Laboratory, Argonne, Illinois 60439*; Michael S. Turner, *Department of Astronomy and Astrophysics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433, NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500, and Department of Physics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433*. (Received 7 September 2000; published 23 February 2001)

Together, the standard theory of big-bang nucleosynthesis (BBN) and the primeval deuterium abundance now very precisely peg the baryon density. Based upon our analysis of the deuterium data and the theoretical uncertainties associated with the BBN predictions, we determine $\Omega_B h^2 = 0.020 \pm 0.002$ (95% C.L.), with the uncertainty from the measured deuterium abundance about twice that from the predicted abundance. We discuss critically the reliability of the BBN baryon density, and in light of possible systematic uncertainties also derive a very conservative range. We conclude that within the standard cosmology and standard theory of BBN a baryon density $\Omega_B h^2 = 0.032$ (the central value implied by recent CMB anisotropy measurements) simply cannot be accommodated. [Phys. Rev. D **63**, 063512 (2001)]

Light sterile neutrino from extra dimensions and four-neutrino solutions to neutrino anomalies. A. Ioannisian and J. W. F. Valle, *Instituto de Física Corpuscular C.S.I.C., Departamento de Física Teòrica, Universitat de València, Edificio Institutos de Paterna,*

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We propose a four-neutrino model that can reconcile the existing data coming from underground experiments in terms of neutrino oscillations, together with the hint from the Liquid Scintillation Neutrino Detector (LSND) experiment and a possible neutrino contribution to the hot dark matter of the Universe. It applies the idea that extra compact dimensions, probed only by gravity and possibly gauge-singlet fields, can lower the fundamental scales such as the Planck, string, or unification scales. Our fourth light neutrino ν_s (s for sterile) is identified with the zero mode of the Kaluza-Klein states. To a first approximation ν_s combines with the ν_μ in order to form a Dirac neutrino with mass in the eV range leaving the other two neutrinos massless. The smallness of this mass scale (suitable for LSND and hot dark matter) arises without appealing either to a seesaw mechanism or to a radiative mechanism, but from the volume factor associated with the canonical normalization of the wave function of the bulk field in the compactified dimensions. On the other hand the splitting between ν_μ and ν_s (atmospheric scale) as well as the mass of the two other neutrinos (solar mass scale) arise from the violation of the fermion number on distant branes. We also discuss alternative scenarios involving flavor-changing interactions. In one of them ν_e can be in the electron-volt range and therefore, be probed in beta decay studies. [Phys. Rev. D **63**, 073002 (2001)]

Neutrino mass spectrum and neutrinoless double beta decay. H. V. Klapdor-Kleingrothaus and H. Päs, *Max-Planck-Institut für Kernphysik, P.O. Box 103980, D-69029 Heidelberg, Germany*; A. Yu. Smirnov, *The Abdus Salam International Center of Theoretical Physics, Strada Costiera 11, Trieste, Italy and Institute for Nuclear Research, RAS, Moscow, Russia*. (Received 29 March 2000; published 2 March 2001)

The relations between the effective Majorana mass of the electron neutrino m_{ee} responsible for neutrinoless double beta decay and the neutrino oscillation parameters are considered. We show that for any specific oscillation pattern m_{ee} can take any value (from zero to the existing upper bound) for normal mass hierarchy and it can have a minimum for inverse hierarchy. This means that oscillation experiments cannot fix in general m_{ee} . Mass ranges for m_{ee} can be predicted in terms of oscillation parameters with additional assumptions about the level of degeneracy and the type of hierarchy of the neutrino mass spectrum. These predictions for m_{ee} are systematically studied in the specific schemes of neutrino mass and flavor which explain the solar and atmospheric neutrino data. The contributions from individual mass eigenstates in terms of oscillation parameters have been quantified. We study the dependence of m_{ee} on the nonoscillation parameters: the overall scale of the neutrino mass and the relative mass phases. We analyze how forthcoming oscillation experiments will improve the predictions for m_{ee} . On the basis

of these studies we evaluate the discovery potential of future $0\nu\beta\beta$ decay searches. The role $0\nu\beta\beta$ decay searches will play in the reconstruction of the neutrino mass spectrum is clarified. The key scales of m_{ee} , which will lead to the discrimination among various schemes, are: $m_{ee} \sim 0.1$ eV and $m_{ee} \sim 0.005$ eV. [Phys. Rev. D **63**, 073005 (2001)]

Leptogenesis and neutrino parameters. D. Falcone and F. Tramontano, *Dipartimento di Scienze Fisiche, Università di Napoli, Complesso di Monte Sant'Angelo, Via Cintia, Napoli, Italy.* (Received 10 November 2000; published 5 March 2001)

We calculate the baryonic asymmetry of the universe in the baryogenesis-via-leptogenesis framework, assuming first a quark-lepton symmetry and then a charged-neutral lepton symmetry. We match the results with the experimentally favored range. In the first case all the oscillation solutions to the solar neutrino problem, except the large mixing matter solution, can lead to the allowed range, but with fine-tuning of the parameters. In the second case the general result is quite similar. Some related theoretical hints are discussed. [Phys. Rev. D **63**, 073007 (2001)]

Neutrinos from SN 1987A, Earth matter effects, and the large mixing angle solution of the solar neutrino problem. C. Lunardini, *SISSA-ISAS, via Beirut 2-4, 34100 Trieste, Italy and INFN, sezione di Trieste, via Valerio 2, 34127 Trieste, Italy*; A. Yu. Smirnov, *The Abdus Salam ICTP, Strada Costiera 11, 34100 Trieste, Italy and Institute for Nuclear Research, RAS, Moscow, Russia.* (Received 25 October 2000; published 7 March 2001)

We study the properties of the oscillation effects in the matter of the Earth on antineutrino fluxes from supernovae. We show that these effects can provide an explanation of the difference in the energy spectra of the events detected by Kamiokande-2 and IMB detectors from SN 1987A as well as the absence of high-energy events with $E \gtrsim 40$ MeV. This explanation requires the neutrino oscillation parameters Δm^2 and $\sin^2 2\theta$ to be in the region of the large mixing angle solution of the solar neutrino problem and the normal mass hierarchy if $|U_{e3}|^2 \gtrsim 10^{-3}$. The hierarchy can be inverted if $|U_{e3}|^2 \lesssim 10^{-3}$. The solution of the solar neutrino problem based on ν_e conversion to a pure sterile state is disfavored by SN 1987A data. [Phys. Rev. D **63**, 073009 (2001)]

Black hole formation in core-collapse supernovae and time-of-flight measurements of the neutrino masses. J. F. Beacom, *Physics Department 161-33, California Institute of Technology, Pasadena, California 91125 and NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*; R. N. Boyd, *Departments of Astronomy and Physics, The Ohio State University, Columbus, Ohio 43210*; A. Mezzacappa, *Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831.* (Received 19 October 2000; published 7 March 2001)

In large stars that have exhausted their nuclear fuel, the stellar core collapses to a hot and dense proto-neutron star that cools by the radiation of neutrinos and antineutrinos of all flavors. Depending on its final mass, this may become either a neutron star or a black hole. Black hole formation may be triggered by mass accretion or a change in the high-density equation of state. We consider the possibility that black hole formation happens when the flux of neutrinos is still measurably high. If this occurs, then the neutrino signal from the supernova will be terminated abruptly (the transition takes $\lesssim 0.5$ ms). The properties and duration of the signal before the cutoff are important measures of both the physics and astrophysics of the cooling proto-neutron star. For the event rates expected in present and proposed detectors, the cutoff will generally appear sharp, thus allowing model-independent time-of-flight mass tests for the neutrinos after the cutoff. If black hole formation occurs relatively early, within a few (~ 1) seconds after core collapse, then the expected luminosities are of order $L_{BH} = 10^{52}$ erg/s per flavor. In this case, the neutrino mass sensitivity can be extraordinary. For a supernova at a distance $D = 10$ kpc, SuperKamiokande can detect a $\bar{\nu}_e$ mass down to 1.8 eV by comparing the arrival times of the high-energy and low-energy neutrinos in $\bar{\nu}_e + p \rightarrow e^+ + n$. This test will also measure the cutoff time, and will thus allow a mass test of ν_μ and ν_τ relative to $\bar{\nu}_e$. Assuming that ν_μ and ν_τ are nearly degenerate, as suggested by the atmospheric neutrino results, masses down to about 6 eV can be probed with a proposed lead detector of mass $M_D = 4$ kton (OMNIS). Remarkably, the neutrino mass sensitivity scales as $(D/L_{BH}M_D)^{1/2}$. Therefore, *direct* sensitivity to all three neutrino masses in the interesting few-eV range is realistically possible; *there are no other known techniques that have this capability.* [Phys. Rev. D **63**, 073011 (2001)]

Four-neutrino oscillations at SNO. M. C. Gonzalez-Garcia and C. Peña-Garay, *Instituto de Física Corpuscular-C.S.I.C., Universitat de València, Edificio Institutos de Paterna, Apt. 22085, E-46071 València, Spain.* (Received 28 November 2000; published 13 March 2001)

We discuss the potential of the Sudbury Neutrino Observatory (SNO) to constrain the four-neutrino mixing schemes favored by the results of all neutrino oscillations experiments. These schemes allow simultaneous transitions of solar ν_e 's into active ν_μ 's, ν_τ 's, and sterile ν_s controlled by the additional parameter $\cos^2(\vartheta_{23})\cos^2(\vartheta_{24})$ and they contain as limiting cases the pure ν_e -active and ν_e -sterile neutrino oscillations. We first obtain the solutions allowed by the existing data in the framework of the BBP00 standard solar model and quantify the corresponding predictions for the charged current and the neutral current to charged current (NC/CC) event ratios at SNO in the different allowed regions as a function of the active-sterile admixture. Our results show that some information on the value of $\cos^2(\vartheta_{23})\cos^2(\vartheta_{24})$ can be obtained by the first SNO measurement of the CC ratio, while considerable improvement on the knowledge of this mixing will be achievable after the measurement of the NC/CC ratio. [Phys. Rev. D **63**, 073013 (2001)]

Solar neutrino results and violation of the equivalence principle: An analysis of the existing data and predictions for SNO.

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Violation of the equivalence principle (VEP) can lead to neutrino oscillation through the nondiagonal coupling of neutrino flavor eigenstates with the gravitational field. The neutrino energy dependence of this oscillation probability is different from that of the usual mass-mixing neutrino oscillations. In this work we explore, in detail, the viability of the VEP hypothesis as a solution to the solar neutrino problem in a two generation scenario with both the active and sterile neutrino alternatives, choosing these states to be massless. To obtain the best-fit values of the oscillation parameters we perform a χ^2 analysis for the total rates of solar neutrinos seen at the chlorine (Homestake), gallium (GALLEX and SAGE), Kamio-kande, and SuperKamiokande (SK) experiments. We find that the goodness of these fits is never satisfactory. It markedly improves, especially for VEP transformation to sterile neutrinos, if the chlorine result is excluded from the analysis. The 1117-day SK data for recoil electron spectrum are also examined for signals of VEP oscillations. For these fits, we consider variations of the standard solar model by allowing the absolute normalizations of the ^8B and hep neutrinos to vary. Here the fits are quite good but the best fit values of the parameters are rather different from those from the total rates fits. A combined fit to the total rates and recoil electron spectrum data is also performed. We present the 90% confidence limit contours for all the three analyses mentioned above. The best-fit parameters obtained from the recoil electron spectrum and the combined analysis of rate and spectrum are used to predict the charge current and scattering electron spectrum at SNO. [Phys. Rev. D **63**, 073014 (2001)]

Crystalline color superconductivity. Mark Alford, Jeffrey A. Bowers, and Krishna Rajagopal, *Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.* (Received 8 September 2000; published 13 March 2001)

In any context in which color superconductivity arises in nature, it is likely to involve pairing between species of quarks with differing chemical potentials. For suitable values of the differences between chemical potentials, Cooper pairs with nonzero total momentum are favored, as was first realized by Larkin, Ovchinnikov, Fulde, and Ferrell (LOFF). Condensates of this sort spontaneously break translational and rotational invariance, leading to gaps which vary periodically in a crystalline pattern. Unlike the original LOFF state, these crystalline quark matter condensates include both spin-zero and spin-one Cooper pairs. We explore the range of parameters for which crystalline color superconductivity arises in the QCD phase diagram. If in some shell within the quark matter core of a neutron star (or within a strange quark star) the quark number densities are such that crystalline color superconductivity arises, rota-

tional vortices may be pinned in this shell, making it a locus for glitch phenomena. [Phys. Rev. D **63**, 074016 (2001)]

Calculation of the decay constants of scalar mesons. C. M. Shakin and Huangsheng Wang, *Department of Physics and Center for Nuclear Theory, Brooklyn College of the City University of New York, Brooklyn, New York 11210.* (Received 18 July 2000; published 13 March 2001)

The purpose of our work is to provide further evidence for the utility of our generalized Nambu–Jona-Lasinio model in describing the properties of light mesons. In this work we develop methods for the calculation of the decay constants of scalar mesons. Our model makes definite predictions of how scalar mesons should be organized into nonets and we use our calculation of the decay constants to support our predictions. The assignment of scalar mesons to various nonets is problematic, with various choices made in the literature for the $\sigma(500-600)$, $f_0(980)$, $a_0(980)$, $f_0(1370)$, $K_0^*(1430)$, and $f_0(1500)$. Maltman has suggested that one can gain information as to how these nonets should be chosen by determining the meson decay constants of the scalar mesons. In particular, he studies the $a_0(980)$, $a_0(1450)$, and $K_0^*(1430)$ resonances using QCD sum rule techniques and other methods. He concludes that the $a_0(980)$ and $K_0^*(1430)$ have similar decay constants and therefore have similar structure. (We have come to the same conclusion by an entirely different analysis, making use of our generalized Nambu–Jona-Lasinio (NJL) model, which includes a covariant model of confinement.) In the case of the $a_0(980)$ we obtain a result for the decay constant that is about 50% larger than that of Maltman, while for the $a_0(1450)$ and $K_0^*(1430)$ our results are somewhat smaller than his. Our results suggest that the $a_0(980)$ may have a significant $K\bar{K}$ component, which would reduce our theoretical value. The implication of our results and those of Maltman for the organization of scalar mesons into nonets is discussed. [Phys. Rev. D **63**, 074017 (2001)]

Counting form factors of twist-two operators. Xiangdong Ji, *Department of Physics, University of Maryland, College Park, Maryland 20742*; Richard F. Lebed, *Department of Physics and Astronomy, Arizona State University, Tempe, Arizona 85287.* (Received 14 December 2000; published 2 March 2001)

We present a simple method to count the number of hadronic form factors based on the partial wave formalism and crossing symmetry. In particular, we show that the number of independent nucleon form factors of spin- n , twist-2 operators (the vector current and energy-momentum tensor being special examples) is $n+1$. These generalized form factors define the generalized (off-forward) parton distributions that have been studied extensively in the recent literature. In proving this result, we also show how the J^{PC} rules for quarkonium states arise in the helicity formalism. [Phys. Rev. D **63**, 076005 (2001)]

Constraints on T-odd, P-even interactions from electric dipole moments, reexamined. A. Kurylov, *Department of Physics, University of Connecticut, Storrs, Connecticut 06269*; G. C. McLaughlin, *Department of Physics and Astronomy, State University of New York, Stony Brook, New York 11794*; M. J. Ramsey-Musolf, *Department of Physics, University of Connecticut, Storrs, Connecticut 06269 and Theory Group, Thomas Jefferson National Accelerator*

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We construct the relationship between nonrenormalizable, effective, time-reversal violating (TV), parity-conserving (PC) interactions of quarks and gauge bosons and various low-energy TVPC and TV parity-violating (PV) observables. Using effective field theory methods, we delineate the scenarios under which experimental limits on permanent electric dipole moments (EDM's) of the electron, neutron, and neutral atoms as well as limits on TVPC observables provide the most stringent bounds on new TVPC interactions. Under scenarios in which parity invariance is restored at short distances, the one-loop EDM of elementary fermions generate the most severe constraints. The limits derived from the atomic EDM of ^{199}Hg are considerably weaker. When parity symmetry remains broken at short distances, direct TVPC search limits provide the least ambiguous bounds. The direct limits follow from TVPC interactions between two quarks. [Phys. Rev. D **63**, 076007 (2001)]

Graphical representation of CP violation effects in neutrinoless double beta decay. K. Matsuda, N. Takeda, and T. Fukuyama, *Department of Physics, Ritsumeikan University, Kusatsu, Shiga 525-8577, Japan*; H. Nishiura, *Department of General Education, Junior College of Osaka Institute of Technology, Asahi-ku, Osaka 535-8585, Japan.* (Received 19 July 2000; published 7 March 2001)

We illustrate the graphical method that gives the constraints on the parameters appearing in the neutrino oscillation experiments and the neutrinoless double beta decay. This method is applicable in three and four generations. Though this method is valid for more general cases, we examine explicitly the cases in which the CP violating factors take ± 1 or $\pm i$ in the neutrinoless double beta decay for illustrative clearance. We also discuss some mass matrix models which lead to the above CP violating factors. [Phys. Rev. D **63**, 077301 (2001)]